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Final Report

Economics of Post-Emergent Swine Manure Application to Cereal Crops in East-Central Saskatchewan

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1. Summary

Post-emergent application of swine manure to cereal crops offers benefits to both swine producers and cereal growers. For hog barns, it extends the time period that manure may be spread on land each year. For farmers, it offers further benefits from manure application when the crop is already growing. Thus, more of the nutrients are being directed toward crop yield and protein content rather than straw.

It has been asserted by many in the agriculture industry that hog barns are not realizing the "true" benefit of swine manure and that farmers "should" be willing to pay more for manure being applied to their land.

The price of manure is determined by scarcity. Due to technological and economic constraints including timing, means of distribution, cost of storage, and transportation, the land resource available for manure application is scarcer than the manure resource itself. This imbalance in scarcity had led to a divergence between the price paid for manure and the value it may have in improving crop revenue.

Scarcity of land within economic spreading distance of barns gives farmers who own this land an "advantageous bargaining position"[1] to bid the price of manure below what its value as an input may be.

The objective of this report is to determine the value of post-emergent swine manure application to farmers relative to other manure application activities such as conventional cropping, fall manure application to cereals, and application to forages. Compared to these alternatives, post-emergent application provided good economic returns. However, the higher than normal protein content of cereals that have received post-emergent manure application means that blending (mixing higher protein with lower protein wheat) is necessary to realize financial benefits.

The results of this study suggest that post-emergent manure application is beneficial so long as the applications take place within one month after seeding, or before the crop is past the three-leaf stage. If there is rainfall shortly after late (post three-leaf stage application), then great benefits can be realized in terms of yield and protein content. However, due to the uncertainty inherent of depending on the timing of such rainfall, it is unwise to apply manure to crops at such a mature stage.

Drought conditions in 2002 significantly increased the variance in the results of this study, and the importance of this cannot be overstated.

[1] Such an advantageous bargaining position could be considered *Opportunism* "self interest seeking with guile" (Williamson, 1979).

2. Introduction

Post-emergent manure application has the potential to increase revenue from cereal crops via greater yield and/or higher protein content. During the 2000, 2001, 2002, and 2003 crop years, PAMI conducted crop trials of post-emergent manure injection (application of manure under the surface using a coulter rather than surface spreading) to determine the affect on crop productivity.

This report is an economic/cost benefit analysis of the post-emergent swine manure application trials conducted by PAMI. It consists of a breakeven analysis and comparison to alternative cropping activities including conventional cropping, fall application of manure, and application of manure to forage crops.

The first section is a list of assumptions that were made to underlie this report. The second section consists of definitions and background information, particularly, emphasizing the importance of nitrogen in cereal cropping. It then presents a review of studies conducted on manure applications to forage crops, as well as fall application of swine manure to cereal crops. The third section is an economic analysis of the data from the PAMI trials to determine the factors affecting revenue from the crop trials. These factors include the application rate of manure, timing of application, protein content and the amount, and timing of precipitation. These values are then used to compare to the costs of application relative to the examples of application to forages and fall application to cereals.

3. Assumptions

Assumptions were made with regards to the price of output (wheat), in terms of price and quality.

- The wheat seeded was (CWRS) Canadian Western Red Spring and it was assumed that the final grade was Number 1.
- The price assumed for this output was that of the combined initial and final payments from the CWB. Since this price varies based upon the protein content, the incremental value of protein was used to determine values that could be attained from blending. It was the protein content from each specific trial result that was used to determine revenue from each trial, **Table 1**.

Table 1. Sample, Gross Revenue Per Acre.

	Application Date June 6, 2000				
	Manure application rate	**Yield bu/acre**	**Protein %**	**Price $/bu**	**Gross Profit $/acre**
Site 1	**Check/No Dist.**	26.3	14.6	5.72	150
	Check	22.9	15.4	6.06	139
	1000 gpa	27.4	15.2	5.98	164
	2000 gpa	29.9	15.6	6.13	183
	3000 gpa	25.4	16.6	6.52	166
Site 2	**Check/No Dist.**	45.1	13.8	5.36	242
	Check	48.4	14.9	5.86	284
	1000 gpa	51.3	15.5	6.10	313
	2000 gpa	49.8	16.6	6.52	325
	3000 gpa	49.6	17.6	6.91	343

Source: Adapted from PAMI trial data and CWB web site.
http://www.cwb.ca/en/contracts/farmer_payments/historical_payments.jsp

- Wheat was chosen as the cereal crop for this study, and prices reflected the protein values found in the wheat from each treatment, replication, and year. For cereal grains other than wheat (e.g., barley or oats), these markets do not offer a premium (or discount) based on protein content. An important exception for prairie producers is malt barley for which protein above 12% can result in rejection for malt applications, since malters require low protein barley. The feed industry is not willing to pay for higher protein, since the barley is often being used as an energy source rather than a protein source. A higher-protein content might be viewed as a residual benefit, but it is not one that the industry is willing, or has to, pay for. (Robert Zentner, 2003).
- The terms check/no dist. and undisturbed are used interchangeably in the report.

- Diminishing returns at higher rates of application (3,000 gpa vs. 2,000 and 1,000 gpa).
- Some conventional fertilizer was applied to the test fields, so that may introduce some distortion in the results for yield and protein benefits from the manure. It is assumed that, as a rule, swine manure would be used as an alternative rather than a complement to conventional fertilizer. Thus, the use, hence cost of conventional fertilizer, would be much reduced for producers using manure.

Averages are used to present and analyze information from the PAMI trials. Although specific details may be "lost" in these averages, the purpose of this report is to establish overall trends (tendencies) in yield results due to post-emergent manure application. For example, some trials were conducted on stubble while others were on summer-fallow. These values have been averaged so as to provide general values for given years and rates of manure application.

4. Definitions and Background

This section presents examples from the literature on the effects of swine manure application to cereals and forages, and to compare them to those results from PAMI's crop trials 2000, 2001, 2002, and 2003 on the post-emergent application of swine manure. This section begins with definitions, and then presents CWB prices for wheat from the 1999 to 2003 crop-years along with transportation costs. Subsequently, technology and methods of swine manure application are examined. This section also presents information on the responsiveness of nitrogen fertilizer costs to price fluctuations in the natural gas market so as to provide an appreciation of farmers exposure to uncertainty for nitrogen fertilizer as an input. In addition, comparisons of the results are made to pre-emergent application (fall application) of swine manure to cereal crops, as well as manure application to forages. The financial returns from these ventures are compared to the results of PAMI's post-emergent crop trials and to SAF values for benefits from conventional inorganic fertilizer applications.

GPA: GPA stands for Imperial gallons per acre of swine manure.

Revenue Per Acre: Revenue per acre depends on two factors, yield (bu/acre) and price ($/bu). The determining factors for the price received for wheat are the wheat variety, grade (#1, #2, #3 etc) and protein content.

***Early, Second, and Late Applications*:** These terms refer to the three manure treatments that were performed by PAMI. These relative terms are used rather than specific dates, since the dates varied from year to year depending on weather or other factors.

Units: Units for yield are bushels per acre, distances are in either miles or kilometers, and temperature is in Celsius. These units used were selected depending upon the data provided in the original PAMI document and/or industry standards.

Blending and the Value of Protein: There is no additional price premium paid by the CWB for protein levels in wheat above 15.5% in 2001, 2002, and 2003, and no premium paid for protein levels above 15% in 2000 crop-year.

> "The reason that the CWB does not pay for higher than 15.5% protein is that there is no market for wheat with protein that high. Most wheat is sold at 13, 13.5, or 14% protein, so the value in higher protein comes through blending which is the job of the Line Company.... Producers may be able to negotiate a better price with their elevator company if they have higher protein levels." Source: Peter Watts CWB representative, 2003

Blending is a process that can take place at an elevator where a farmer negotiates with an elevator agent to mix a given amount of high protein wheat (i.e. 17%) with a volume of lower protein wheat (i.e. 12%) to achieve a uniform blend of wheat with predetermined protein content, e.g., 15.5% protein (McGrath, 2003). This would benefit the farmer since it offers the opportunity to realize the "true" value of the protein in his/her product.[2]

Prices for wheat for the trial years are detailed in **Table 2.**

Table 2. Canadian Wheat Board Payments (in store Vancouver or St. Lawrence).

YEAR		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
WHEAT CWRS[3]	% Protein Content	$/bu	$/bu	$/bu	$/bu	$/bu
Hypothetical value @ 18.5	**18.5**	**7.26**	**7.43**	**7.42**	**7.66**	**4.74**
Hypothetical value @ 18.4	**18.4**	**7.23**	**7.39**	**7.38**	**7.64**	**4.72**
Hypothetical value @ 18.3	**18.3**	**7.19**	**7.35**	**7.34**	**7.63**	**4.71**
Hypothetical value @ 18.2	**18.2**	**7.15**	**7.31**	**7.30**	**7.61**	**4.69**
Hypothetical value @ 18.1	**18.1**	**7.11**	**7.27**	**7.26**	**7.60**	**4.67**
Hypothetical value @ 18.0	**18.0**	**7.07**	**7.23**	**7.22**	**7.58**	**4.65**
Hypothetical value @ 17.9	**17.9**	**7.03**	**7.20**	**7.19**	**7.56**	**4.63**
Hypothetical value @ 17.8	**17.8**	**6.99**	**7.16**	**7.15**	**7.55**	**4.61**
Hypothetical value @ 17.7	**17.7**	**6.95**	**7.12**	**7.11**	**7.53**	**4.59**
Hypothetical value @ 17.6	**17.6**	**6.91**	**7.08**	**7.07**	**7.52**	**4.57**
Hypothetical value @ 17.5	**17.5**	**6.87**	**7.04**	**7.03**	**7.50**	**4.55**
Hypothetical value @ 17.4	**17.4**	**6.84**	**7.00**	**6.99**	**7.48**	**4.53**
Hypothetical value @ 17.3	**17.3**	**6.80**	**6.96**	**6.95**	**7.47**	**4.51**
Hypothetical value @ 17.2	**17.2**	**6.76**	**6.92**	**6.91**	**7.45**	**4.50**
Hypothetical value @ 17.1	**17.1**	**6.72**	**6.88**	**6.87**	**7.44**	**4.48**
Hypothetical value @ 17.0	**17.0**	**6.68**	**6.85**	**6.84**	**7.42**	**4.46**
Hypothetical value @ 16.9	**16.9**	**6.64**	**6.81**	**6.80**	**7.40**	**4.44**
Hypothetical value @ 16.8	**16.8**	**6.60**	**6.77**	**6.76**	**7.39**	**4.42**
Hypothetical value @ 16.7	**16.7**	**6.56**	**6.73**	**6.72**	**7.37**	**4.40**
Hypothetical value @ 16.6	**16.6**	**6.52**	**6.69**	**6.68**	**7.36**	**4.38**
Hypothetical value @ 16.5	**16.5**	**6.49**	**6.65**	**6.64**	**7.34**	**4.36**
Hypothetical value @ 16.4	**16.4**	**6.45**	**6.61**	**6.60**	**7.32**	**4.34**
Hypothetical value @ 16.3	**16.3**	**6.41**	**6.57**	**6.56**	**7.31**	**4.32**
Hypothetical value @ 16.2	**16.2**	**6.37**	**6.53**	**6.52**	**7.29**	**4.30**
Hypothetical value @ 16.1	**16.1**	**6.33**	**6.49**	**6.48**	**7.28**	**4.28**
Hypothetical value @ 16.0	**16.0**	**6.29**	**6.46**	**6.45**	**7.26**	**4.27**
Hypothetical value @ 15.9	**15.9**	**6.25**	**6.42**	**6.41**	**7.24**	**4.25**
Hypothetical value @ 15.8	**15.8**	**6.21**	**6.38**	**6.37**	**7.23**	**4.23**
Hypothetical value @ 15.7	**15.7**	**6.17**	**6.34**	**6.33**	**7.21**	**4.21**
Hypothetical value @ 15.6	**15.6**	**6.13**	**6.30**	**6.29**	**7.20**	**4.19**

[2] Information on blending to maximize returns from protein is taken from an interview with Humboldt area farmer, Les McGrath.
[3] **Bolded** values are either calculated and/or hypothetical values derived from averages.

YEAR		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
WHEAT CWRS[3]	% Protein Content	$/bu	$/bu	$/bu	$/bu	$/bu
No. 1 Canada Western Red Spring (15.5)	15.5	6.10	6.26	6.25	7.18	4.17
No. 1 Canada Western Red Spring (15.4)	15.4	6.06	6.22	6.23	7.15	4.15
No. 1 Canada Western Red Spring (15.3)	15.3	6.02	6.18	6.22	7.14	4.12
No. 1 Canada Western Red Spring (15.2)	15.2	5.98	6.14	6.19	7.12	4.10
No. 1 Canada Western Red Spring (15.1)	15.1	5.94	6.10	6.18	7.10	4.07
No. 1 Canada Western Red Spring (15.0)	15.0	5.90	6.06	6.15	7.09	4.05
No. 1 Canada Western Red Spring (14.9)	14.9	5.86	6.02	6.14	7.06	4.03
No. 1 Canada Western Red Spring (14.8)	14.8	5.81	5.98	6.12	7.05	4.00
No. 1 Canada Western Red Spring (14.7)	14.7	5.77	5.94	6.10	7.02	3.98
No. 1 Canada Western Red Spring (14.6)	14.6	5.72	5.90	6.09	7.01	3.95
No. 1 Canada Western Red Spring (14.5)	14.5	5.67	5.86	6.07	6.98	3.93
No. 1 Canada Western Red Spring (14.4)	14.4	5.63	5.82	6.05	6.97	3.90
No. 1 Canada Western Red Spring (14.3)	14.3	5.58	5.78	6.03	6.95	3.88
No. 1 Canada Western Red Spring (14.2)	14.2	5.54	5.74	6.02	6.94	3.86
No. 1 Canada Western Red Spring (14.1)	14.1	5.49	5.70	6.00	6.91	3.84
No. 1 Canada Western Red Spring (14.0)	14.0	5.44	5.66	5.98	6.89	3.82
No. 1 Canada Western Red Spring (13.9)	13.9	5.40	5.63	5.97	6.88	3.79
No. 1 Canada Western Red Spring (13.8)	13.8	5.36	5.60	5.95	6.86	3.77
No. 1 Canada Western Red Spring (13.7)	13.7	5.32	5.57	5.94	6.85	3.75
No. 1 Canada Western Red Spring (13.6)	13.6	5.28	5.54	5.92	6.83	3.73
No. 1 Canada Western Red Spring (13.5)	13.5	5.24	5.51	5.91	6.80	3.71
No. 1 Canada Western Red Spring (13.4)	13.4	5.20	5.48	5.89	6.79	3.69
No. 1 Canada Western Red Spring (13.3)	13.3	5.17	5.45	5.88	6.78	3.67
No. 1 Canada Western Red Spring (13.2)	13.2	5.14	5.42	5.86	6.77	3.65
No. 1 Canada Western Red Spring (13.1)	13.1	5.11	5.38	5.85	6.75	3.64
No. 1 Canada Western Red Spring (13.0)	13.0	5.07	5.35	5.83	6.74	3.62
No. 1 Canada Western Red Spring (12.9)	12.9	5.04	5.32	5.82	6.73	3.60
No. 1 Canada Western Red Spring (12.8)	12.8	5.01	5.29	5.80	6.71	3.59
No. 1 Canada Western Red Spring (12.7)	12.7	4.98	5.26	5.79	6.71	3.57
No. 1 Canada Western Red Spring (12.6)	12.6	4.95	5.22	5.77	6.69	3.55
No. 1 Canada Western Red Spring (12.5)	12.5	4.91	5.19	5.76	6.69	3.54
No. 1 Canada Western Red Spring (12.4)	12.4	4.88	5.17	5.74	6.67	3.52
No. 1 Canada Western Red Spring (12.3)	12.3	4.84	5.14	5.73	6.65	3.51

YEAR		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
WHEAT CWRS[3]	% Protein Content	$/bu	$/bu	$/bu	$/bu	$/bu
No. 1 Canada Western Red Spring (12.2)	12.2	4.80	5.12	5.72	6.65	3.49
No. 1 Canada Western Red Spring (12.1)	12.1	4.77	5.09	5.71	6.63	3.47
No. 1 Canada Western Red Spring (12.0)	12.0	4.73	5.07	5.69	6.62	3.46
No.1 Canada Western Red Spring (11.9)	11.9					3.44
No.1 Canada Western Red Spring (11.8)	11.8					3.42
No.1 Canada Western Red Spring (11.7)	11.7					3.41
No.1 Canada Western Red Spring (11.6)	11.6					3.39
No.1 Canada Western Red Spring (11.5)	11.5					3.38
No.1 Canada Western Red Spring (11.4)	11.4					3.36
No.1 Canada Western Red Spring (11.3)	11.3					3.34
No.1 Canada Western Red Spring (11.2)	11.2					3.33
No.1 Canada Western Red Spring (11.1)	11.1					3.31

Source: Adapted from CWB web site

http://www.cwb.ca/en/contracts/farmer_payments/historical_payments.jsp

The values used in **Table 2** were used to calculate revenue for the trials. Bolded values are those calculated showing returns from the blending of very high protein wheat (i.e. above those for CWB prices). These hypothetical prices were derived by taking the average additional value for each 0.1% protein difference in the CWB wheat price schedule and adding these increments to the values for which the CWB does not currently pay a protein premium. The rational being, that the additional value for each protein increment will be realized as a result of blending.

4.1 Rail Transportation Costs

The transportation of wheat to port is an unavoidable cost for those producing cereals for human consumption and export. Due to the great distance from population centers and points of export, the cost of transportation represents from 15 to 30% of a farmer's total production costs. For example, rail transportation from Humboldt to Vancouver averages $0.97 per bushel, **Table 3.**

Table 3. Rail Transport Cost From Humboldt to Vancouver.

Year	Cost ($/bushel)
2000-2001	$1.0000
1999-2000	$0.9572
1998-1999	$0.9552
1997-1998	$0.9662
1996-1997	$0.9471
Average	**$0.97**

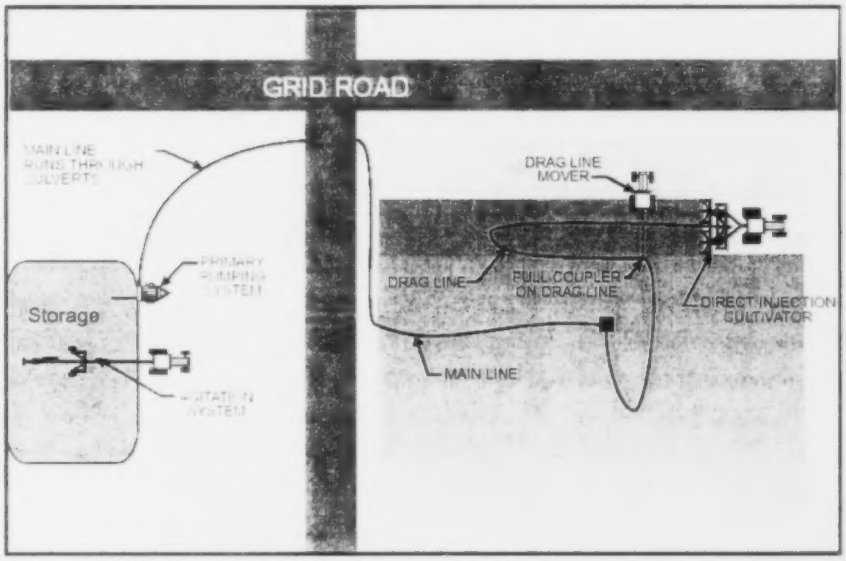
Source: Brian Bell Canadian Transportation Agency (Brian.Bell@cta-otc.gc.ca)

These values are for rail transportation only and do not include elevation, storage, and handling costs.

4.2 Manure Injection Technology and Costs

Manure injection is a specialized and labor-intensive activity requiring some specialized equipment and a skilled workforce, **Figure 1**. At the time of writing, industry standards are such that a manure injection contractor requires at least 1,000,000 gallons of manure at a hog barn site to be economically viable to inject manure (Sands, 2003).

The process of manure injection to agricultural land is illustrated in **Figure 1**.



Source: PAMI, 1997

Figure 1. Manure Injection.

Most hog barn lagoons[4] (earthen manure storage) are designed to store manure for a maximum of 400 days (often volume of these lagoons exceeds 1,000,000 gallons), after which they must be emptied. An agitation system (usually two agitators with tractors are required) ensures that the manure is relatively homogeneous and that solids are not settled at the bottom covered by a layer of liquid. The "homogenized" manure is then pumped to the injection machinery, via a hose, to the field. The hose must often cross roads, pass through culverts, and be directed around obstacles like power poles and buildings. If the distance to the field is greater than two miles or, if there are many bends in the hose, then an additional booster pump (and tractor) is required. A hose-humper is required to direct the hose behind the tractor and injection machine (Sands, 2003).

[4] In **Figure 1**, storage refers to the manure storage lagoon.

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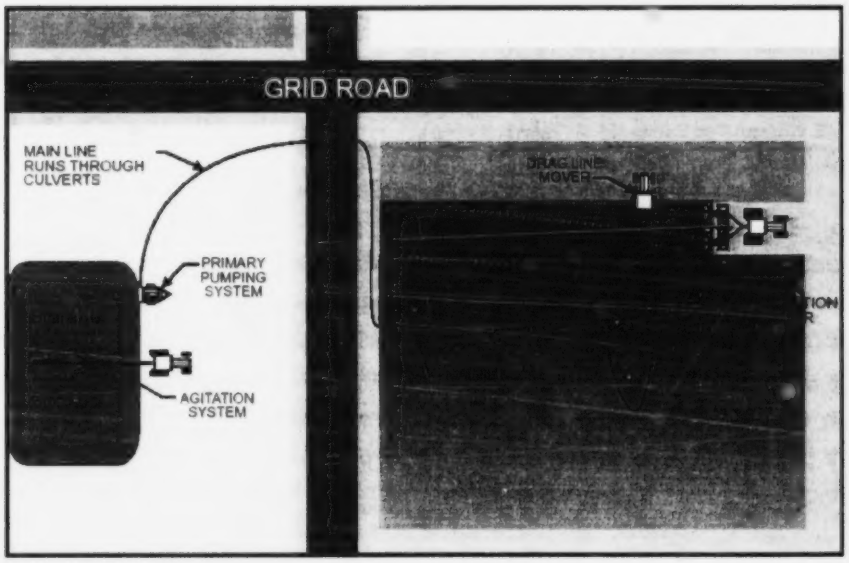

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[4] In **Figure 1**, storage refers to the manure storage lagoon.

The injection operation also requires two one-ton trucks and a flat deck truck to maintain field operations, as well as a semi tractor and lowboy trailer for transport. The costs of this equipment are shown in **Table 4**.

Table 4. Manure Injection Capital Costs.

Equipment	Number of Items	Price	Total Cost
Tractor 180 hp (one with 3 point hitch)	3	$150,000	$450,000
Agitators	2	$20,000	$40,000
Pump	2	$1,500	$3,000
Trucks, One Ton	2	$40,000	$80,000
Hose Humper	1	$2,000	$2,000
Injector unit with 2 miles of hose	1	$325,000	$325,000
Semi Tractor Unit (used)	1	$35,000	$35,000
Semi Low Boy (used)	1	$25,000	$25,000
Tandem Truck With Flatdeck (used)	1	$30,000	$30,000
Total			**$990,000**

Source: Dean Newdorf (306 225 5723 or 306 222 6677)

Thus, roughly $1,000,000 of capital equipment is required to start and operate a manure injection system/business. This equipment would be capable of injecting 1,000,000 gallons of manure per day, operating 24 hours per day.

Given these capital costs and the associated injection capabilities, the following costs as indicated in **Table 5** apply to manure injection in 2003.

Table 5. Manure Injection Prices.

Radius (miles)	Price per gallon
1-2	$0.0097
2-2.5	$0.0115
2.5-3	$0.0135

Source: Industry Standard

An industry representative provided these costs; however, at their request, their names have not been mentioned.

4.3 Fertilizer Use in Prairie Agriculture

Fertilizer use has increased dramatically in Saskatchewan since the early 1970s. This is particularly so for nitrogen based fertilizer, although phosphate fertilizer usage has increased as well. During this period, farmers gradually increased cropped acreage and reduced fallow acreage. This resulted in large increases in stubble cropping, which requires additions of nitrogen fertilizer. Declining soil quality (due to frequent fallowing

and excessive tillage) has also been a factor in increased use of nitrogen fertilizer recommendations. Nitrogen fertilizer is often required on summerfallow fields as well.

From the mid 1980s until the early 1990s, fertilizer consumption leveled off. Declining grain prices and tighter profit margins, during this period, may have caused this. However, the return to higher grain prices in 1995 and 1996 revived interest in higher fertilizer usage. A farmer's decision to use fertilizer involves both the basic decision whether to apply fertilizer and to determine the most economical rate of application.

The economics of fertilizer use is heavily dependent upon what crop is grown. For example, canola requires greater amounts of macronutrients such as N, P, K, and S, whereas, wheat under a similar situation will need primarily N and P. Since the focus of this report is on cereal crop production, nitrogen is the nutrient of primary interest.

The method of determining the cost of nitrogen when the commercial product is 46-0-0 priced at, i.e. $350/tonne is as follows.

46-0-0 46.0% N = 46/100 x 2204.6 lb. = 1014.1 lb. N/tonne
Therefore cost of N is $350/1014.1 lb. = $0.345/lb.

Formula 1. Conventional Fertilizer Nutritive Capacity

The benefits of conventional fertilizer application (based upon a wheat price of $5.00 per bushel) are illustrated in **Table 6**.

Table 6. Benefits of Nitrogen Application.

Nitrogen Fertilizer Applied (lb./acre)	Yield	Gross Revenue per acre	Marginal Revenue per acre	Cost of N @ $0.30/lb	Marginal Cost @ N=$0.30/lb.	Cost of N @ $0.50/lb.	Marginal Cost @ N=$0.50/lb.
0	30.0	$150.00		$0.00	$0.00	$0.00	
10	32.5	$162.50	$12.50	$3.00	$3.00	$5.00	$5.00
20	34.7	$173.50	$11.00	$6.00	$3.00	$10.00	$5.00
30	36.5	$182.50	$9.00	$9.00	$3.00	$15.00	$5.00
40	38.0	$190.00	$7.50	$12.00	$3.00	$20.00	$5.00
50	39.2	$196.00	$6.00	$15.00	$3.00	$25.00	$5.00
60	40.0	$200.00	$4.00	$18.00	$3.00	$30.00	$5.00
70	40.5	$202.50	$2.50	$21.00	$3.00	$35.00	$5.00
80	40.5	$202.50	$0.00	$24.00	$3.00	$40.00	$5.00
90	40.5	$202.50	$0.00	$27.00	$3.00	$45.00	$5.00
100	40.5	$202.50	$0.00	$30.00	$3.00	$50.00	$5.00

Source: adapted from calculations by Robert Zentner and
http://www.agr.gov.sk.ca/DOCS/econ_farm_man/production/Cereals/fertilizer99.pdf

The first 10 pounds of fertilizer adds 2.5 bushels per acre to yield, the second 10 pounds adds 2.2 bushels per acre, and so on until at 80 pounds per acre no further yield increase occurs. This schedule illustrates the principle of diminishing returns. The amount of nitrogen that will result in the most profit can be determined based on fertilizer and grain prices.

The marginal cost of each 10 lbs. of fertilizer is $3.00 at $0.30/lb and $5.00 at $0.50/lb. Where the marginal benefit of each additional increment in fertilizer is equal (or not yet less than) the marginal cost of the corresponding increment of fertilizer determines the optimal rate of application. As can be seen, from the example in **Table 6**, the greatest marginal benefit to applying fertilizer is realized at 60 lb/acre when nitrogen prices are $0.30/lb and 50 lb/acre when nitrogen costs $0.50 per acre. This means that during periods of decreasing grain prices and/or increasing fertilizer costs, the amount of fertilizer used should be reduced to maximize profit. Conversely, during periods of increasing grain prices and/or declining fertilizer costs, the amount of fertilizer used should increase.

Given the previously illustrated benefits of nitrogen application to crops, the sensitivity of farm profitability is dependent upon the cost of nitrogen fertilizer. Cost trends for nitrogen fertilizer and the correlation with natural gas prices is illustrated in **Figure 2**.

Table 6. Benefits of Nitrogen Application.

Nitrogen Fertilizer Applied (lb./acre)	Yield	Gross Revenue per acre	Marginal Revenue per acre	Cost of N @ $0.30/lb	Marginal Cost @ N=$0.30/lb.	Cost of N @ $0.50/lb.	Marginal Cost @ N=$0.50/lb.
0	30.0	$150.00		$0.00	$0.00	$0.00	
10	32.5	$162.50	$12.50	$3.00	$3.00	$5.00	$5.00
20	34.7	$173.50	$11.00	$6.00	$3.00	$10.00	$5.00
30	36.5	$182.50	$9.00	$9.00	$3.00	$15.00	$5.00
40	38.0	$190.00	$7.50	$12.00	$3.00	$20.00	$5.00
50	39.2	$196.00	$6.00	$15.00	$3.00	$25.00	$5.00
60	40.0	$200.00	$4.00	$18.00	$3.00	$30.00	$5.00
70	40.5	$202.50	$2.50	$21.00	$3.00	$35.00	$5.00
80	40.5	$202.50	$0.00	$24.00	$3.00	$40.00	$5.00
90	40.5	$202.50	$0.00	$27.00	$3.00	$45.00	$5.00
100	40.5	$202.50	$0.00	$30.00	$3.00	$50.00	$5.00

Source: adapted from calculations by Robert Zentner and
http://www.agr.gov.sk.ca/DOCS/econ_farm_man/production/Cereals/fertilizer99.pdf

The first 10 pounds of fertilizer adds 2.5 bushels per acre to yield, the second 10 pounds adds 2.2 bushels per acre, and so on until at 80 pounds per acre no further yield increase occurs. This schedule illustrates the principle of diminishing returns. The amount of nitrogen that will result in the most profit can be determined based on fertilizer and grain prices.

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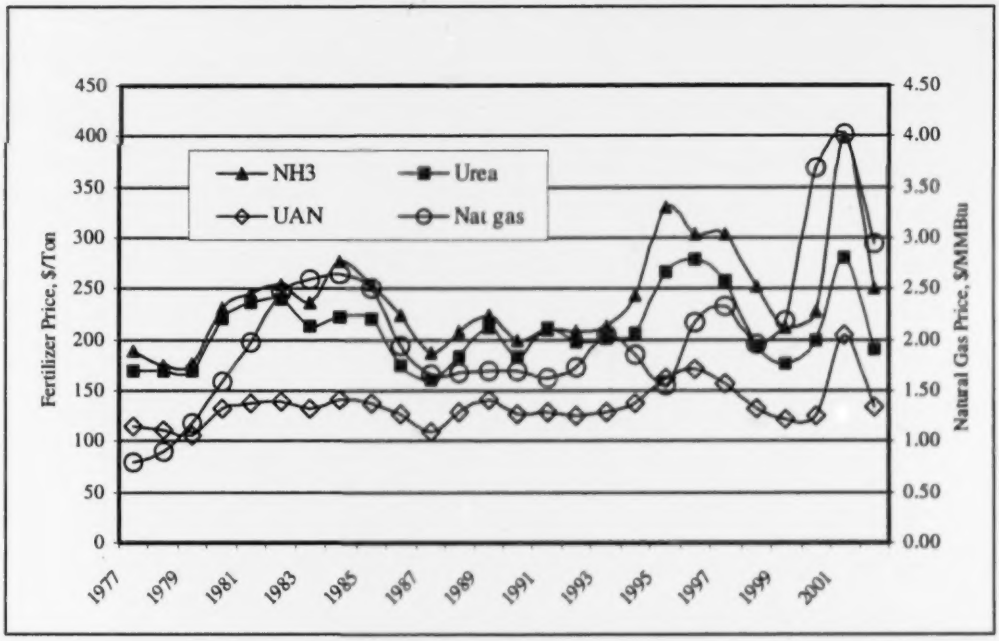
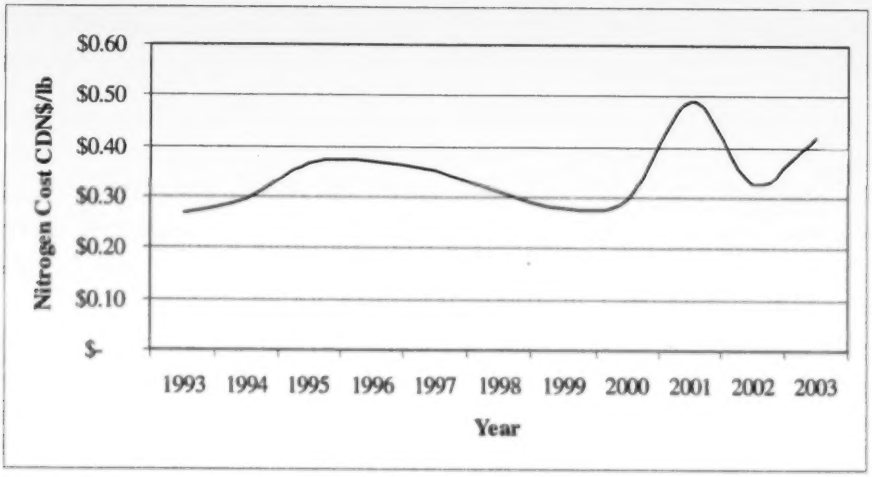
Given the previously illustrated benefits of nitrogen application to crops, the sensitivity of farm profitability is dependent upon the cost of nitrogen fertilizer. Cost trends for nitrogen fertilizer and the correlation with natural gas prices is illustrated in **Figure 2**.



Source: Adapted from information received from "Kevin Dhuyvetter"

Figure 2. Annual Natural Gas vs. Nitrogen Fertilizer Prices.

Since natural gas represents an important input into nitrogen fertilizer production, the price of nitrogen fertilizer mimics closely the price of natural gas. This demonstrates a strong correlation between the price of natural gas and the cost of nitrogen fertilizer. This is further presented in **Figure 3**.



Sources:"Kevin Dhuyvetter" kdhuyvet@mail.agecon.ksu.edu
http://www.bankofcanada.ca/en/exchange-avg.htm
"Jeff Schoenau" schoenau@sask.usask.ca

Figure 3. Price of Nitrogen for Agriculture Uses in Saskatchewan.

As can be seen, from 1993 to 2000, the price of nitrogen was relatively stable between $0.30 and $0.40 per lb. After the beginning of 2000, when the price of natural gas increased drastically, the cost of nitrogen fertilizer also increased sharply. This resulted in prices of almost $0.50 per lb. Although the cost of nitrogen again decreased in 2002, it was again on an upward trend in 2003. This increase corresponds to increased natural gas prices, which are shown in **Table 7**.

Table 7. Prices for Natural Gas 2003.

	January	February	March	April	May
CDN$/GJ	$5.88	$6.83	$8.94	$5.88	$5.73
US$/GJ	$4.17	$4.84	$6.34	$4.17	$4.06
US$/MMBtu	$3.96	$4.60	$6.02	$3.96	$3.86

Source: http://www.energy.gov.ab.ca/gmd/gas/agrp.asp

According to Allan Greenspan, Chairman of the U.S. Federal Reserve, such upward volatility in the natural gas market, as is illustrated in **Table 7**, can be expected throughout the mid part of the decade. Consequently, upward pressure on nitrogen costs will undoubtedly follow. This enforces the demand for alternative sources of nitrogen, such as, that found in swine manure.

5. Comparison 1, Fall Manure Application to Cereal Crops

Field experiments were conducted at two sites, Burr and Dixon, in east central Saskatchewan near Humboldt. These hog manure trials took place over three years (1997, 1998, and 1999) and consisted of a check and seven trials in which three rates of manure were injected at 30 cm spacing. These trials are documented within a 2001 report titled *Economic Returns and Hauling Distance of Hog and Cattle Manure* by C. N. Nagy, J. J. Schoenau, R. A. Schoney. Canola was grown in 1997, Canadian Western Red Spring Wheat (CWRS) in 1998, and Hulless Barley in 1999. The November 1997 street price was used for Canola ($8.60/bu), the Canadian Wheat Board October Pool Return Outlook for #1 CWRS ($5.65/bu), and Select Two-row Hulless Barley ($4.51/bu) was used in 1998 and 1999, respectively.

As the studies were looking at results of manure application over several years, to both cereal crops and to canola, it introduces additional differences. These include the residual benefits from manure being realized by crops over several years, possible confusion due to the final results being presented as overall revenues, and not being divided according to crop. Although attempts were made to distill these results, insufficient information was available at the time of writing.

5.1 Manure Handling Costs for Dixon and Burr Sites

Loading, application, and hauling costs were calculated for a 20 million-litre (4.4 million-gallon) lagoon. Tractor, pump, injector, and tank costs were used in constructing budgets for hauling liquid manure, based on a worksheet developed by PAMI[1]. The machinery complement was sized to the lagoon capacity and application rate. Hauling costs are based on the average kilometer per hectare hauling distance to the available land base at a specific application rate for a one in two-year frequency. Custom liquid manure hauling rates are $1.65/1,000 litres for surface applied and $1.87/1,000 litres for injection within a 2.4 km hauling distance, plus the cost of two tractors and labor to run the pumps. The injection cost converted to imperial values equals $0.0084898 per gallon. Values for each application rate are shown in **Table 8.**

Table 8. Manure Transportation and Injection Costs.

gpa[5]	Cost per Acre
3,300	$28
6,242	$53
6,777	$58
12,485	$106
13,198	$112
24,077	$204

Source: Adapted from Nagy, Schoenau and Schoney, 2001

5.2 Results from Burr and Dixon Site Studies

A three-year period was used to determine the residual effects of manure application over that time period, as well as to observe the annual affects of manure application on the same piece of land. Comparisons between results of this fall application study and those of the post-emergent application study are complicated by several factors. These include different prevailing weather and other environmental conditions, as well as differences in output (crop) prices and input costs (i.e. costs of transportation and injection). Results are presented for the Burr Site in **Tables 9** and **10**.

Table 9. Returns above Manure Application Costs at Burr ($/acre).

	1997		1998		1999		Two year	Three Year	Average
Treatment	**$/acre**	**gpa**	**$/acre**	**gpa**	**$/acre**	**gpa**	**$/acre**	**$/acre**	**$/acre**
Check	69	-	38	-	60	-	107	167	71
Trial 1	104	6,242	44	-	79	-	148	226	99
Trial 2	134	6,242	33	6,242	93	6,242	167	260	111
Trial 3	17	12,485	81	-	101	-	98	199	65
Trial 4	74	12,485	62	-	83	12,485	136	218	90
Trial 5	68	12,485	13	12,485	85	12,485	81	166	54
Trial 6	-107	24,077	78	-	124	-	-29	95	-19
Trial 7	-111	24,077	-35	24,077	60	24,077	-147	-86	-98

Source: Adapted from Nagy, Schoenau and Schoney, 2001

As can be seen in **Table 9**, Trial 2 had the highest return in 1997, the highest total return summed over the three trial years, and the highest average return per acre. This Trial consisted of equal applications of 6,242 gpa of manure annually.

The results of manure treatment can also be represented in terms of *benefit per acre*, in which, the value for each trial is reduced by the amount of the "check" (no treatment) trial. This, in turn, reduces the affect of differences between annual conditions and more accurately represents the benefits (losses) due to manure applications. This is shown in **Table 10**.

Table 10. Benefit per acre, Burr Site.

	1997 $/acre	1998 $/acre	1999 $/acre	Two Year $/acre	Three Year $/acre	Average $/acre
Trial 1	35	6	18	41	59	20
Trial 2	65	-5	32	60	93	31
Trial 3	-51	43	41	-9	32	11
Trial 4	5	23	22	29	51	17
Trial 5	-1	-25	25	-26	-1	0
Trial 6	-176	40	64	-136	-72	-24
Trial 7	-180	-73	0	-253	-253	-84

Source: Adapted from Nagy, Schoenau and Schoney, 2001

Although Trial 2 did not have the maximum benefit in each year, it did provide the highest benefit when summed over two and three years. As can be seen, the annual application of large volumes on manure (24,077 gpa) in Trial 7 resulted in yield reductions on the performance of the crop. This may be due to excessive nutrients "burning" the crop.

Results for the Dixon Site are shown in **Tables 11** and **12**.

Table 11. Dixon Hog Manure Revenue after Variable Cost ($/acre).

	1997		1998		1999		Two year	Three Year	Average
Treatment	**$/acre**	**gpa**	**$/acre**	**gpa**	**$/acre**	**gpa**	**$/acre**	**$/acre**	**$/acre**
Check	92	-	21	-	93	-	113	206	76
Trial 1	180	3,300	31	-	94	-	211	305	140
Trial 2	168	3,300	15	3,300	151	3,300	182	334	121
Trial 3	202	6,777	33	-	93	3,300	235	328	157
Trial 4	200	6,777	33	-	125	6,777	233	357	155
Trial 5	177	6,777	24	6,777	132	6,777	202	334	134
Trial 6	132	13,198	77	-	99	-	209	308	140
Trial 7	136	13,198	-8	13,198	72	13,198	128	200	85

Source: Adapted from Nagy, Schoenau and Schoney, 2001

As can be seen in **Table 11**, Trial 4 had the highest total return summed over the three trial years and was only $1.00 per acre less than Trial 5 for the average over three. Trial 4 consisted of one application of 6,777 gpa in 1997 and one application of 6,777gpa in 1999. It is important to note that having two applications would incur greater input costs than a single application.

These results can also be represented in terms of *benefit per acre*, see **Table 12**.

[5] Volumes for gpa are not "round" numbers due to conversions from metric to imperial.

Table 12. Benefit per acre, Dixon Site.

	1997 $/acre	1998 $/acre	1999 $/acre	Two Year $/acre	Three Year $/acre	Average $/acre
Trial 1	116	9	2	125	127	42
Trial 2	104	21	58	125	183	61
Trial 3	168	11	0	179	180	60
Trial 4	166	12	32	177	209	70
Trial 5	143	60	39	203	242	81
Trial 6	152	56	6	208	214	71
Trial 7	156	82	-21	239	218	73

Source: Adapted from Nagy, Schoenau and Schoney, 2001

As can be seen, Trial 5 retained the maximum benefit for the three-year average, and the annual application of large volumes on manure (24,077 gpa) in Trial 7 resulted in diminishing returns to the performance of the crop.

The information attained from this study of fall application of swine manure will be used in the comparison section in this report to contrast with the results of post-emergent application of swine manure to cereal crops.

Table 10. Benefit per acre, Burr Site.

	1997	1998	1999	Two Year	Three Year	Average
	$/acre	$/acre	$/acre	$/acre	$/acre	$/acre
Trial 1	35	6	18	41	59	20
Trial 2	65	-5	32	60	93	31
Trial 3	-51	43	41	-9	32	11
Trial 4	5	23	22	29	51	17
Trial 5	-1	-25	25	-26	-1	0
Trial 6	-176	40	64	-136	-72	-24
Trial 7	-180	-73	0	-253	-253	-84

Source: Adapted from Nagy, Schoenau and Schoney, 2001

Although Trial 2 did not have the maximum benefit in each year, it did provide the highest benefit when summed over two and three years. As can be seen, the annual application of large volumes on manure (24,077 gpa) in Trial 7 resulted in yield reductions on the performance of the crop. This may be due to excessive nutrients "burning" the crop.

Results for the Dixon Site are shown in **Tables 11** and **12**.

Table 11. Dixon Hog Manure Revenue after Variable Cost ($/acre).

	1997		1998		1999		Two year	Three Year	Average
Treatment	**$/acre**	**gpa**	**$/acre**	**gpa**	**$/acre**	**gpa**	**$/acre**	**$/acre**	**$/acre**
Check	92	-	21	-	93	-	113	206	76
Trial 1	180	3,300	31	-	94	-	211	305	140
Trial 2	168	3,300	15	3,300	151	3,300	182	334	121
Trial 3	202	6,777	33	-	93	3,300	235	328	157
Trial 4	200	6,777	33	-	125	6,777	233	357	155
Trial 5	177	6,777	24	6,777	132	6,777	202	334	134
Trial 6	132	13,198	77	-	99	-	209	308	140
Trial 7	136	13,198	-8	13,198	72	13,198	128	200	85

Source: Adapted from Nagy, Schoenau and Schoney, 2001

As can be seen in **Table 11**, Trial 4 had the highest total return summed over the three trial years and was only $1.00 per acre less than Trial 5 for the average over three. Trial 4 consisted of one application of 6,777 gpa in 1997 and one application of 6,777gpa in 1999. It is important to note that having two applications would incur greater input costs than a single application.

These results can also be represented in terms of *benefit per acre*, see **Table 12**.

[1] Volumes for gpa are not "round" numbers due to conversions from metric to imperial.

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	1997 $/acre	1998 $/acre	1999 $/acre	Two Year $/acre	Three Year $/acre	Average $/acre
Trial 1	116	9	2	125	127	42
Trial 2	104	21	58	125	183	61
Trial 3	168	11	0	179	180	60
Trial 4	166	12	32	177	209	70
Trial 5	143	60	39	203	242	81
Trial 6	152	56	6	208	214	71
Trial 7	156	82	-21	239	218	73

Source: Adapted from Nagy, Schoenau and Schoney, 2001

As can be seen, Trial 5 retained the maximum benefit for the three-year average, and the annual application of large volumes on manure (24,077 gpa) in Trial 7 resulted in diminishing returns to the performance of the crop.

The information attained from this study of fall application of swine manure will be used in the comparison section in this report to contrast with the results of post-emergent application of swine manure to cereal crops.

6. Comparison 2, Application to Forage Crops

Agrologists have promoted cultivation of forage crops as a means of improving soil fertility, minimization of erosion, and as a feed source for the livestock industry. The single case of BSE identified in Alberta in 2003 placed the growth of the Canadian livestock industry, and the corresponding demand for feed stuffs, into question. However, given the suitability of forage crops to manure application, it remains an apt comparison to post-emergent manure application to cereal crops.

Production and value of forage production in Saskatchewan has varied during the period 1992 to 2002, **Table 13**.

Table 13. Saskatchewan Tame Hay Production and Value 1992 to 2002.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Avg.
Production Mtonnes	3.0	2.5	4.0	2.2	3.4	1.6	2.8	4.1	3.8	2.1	2.0	2.9
Value million $	156	165	224	137	306	149	242	260	248	183	245	206
Yield Tonnes/Acre	1.2	1.0	1.4	0.8	1.3	0.6	1.1	1.5	1.2	0.8	0.7	1.1
Farm Price $/tonne	52	65	56	63	90	91	86	63	66	86	124	73

Source: adapted from
http://www.agr.gov.sk.ca/DOCS/statistics/finance/other/Handbook01.pdf
Dale Sikora, Agriculture Information Data Development, Policy Branch
dsikora@agr.gov.sk.ca

As can be seen in **Table 13** there is a clear price response to the supply of forages in the market.

6.1 Liquid Swine Manure Application to Forages

Economic returns from liquid swine manure application to forages have been detailed in a project titled, *Liquid Swine Manure Application to Forage Soil: Effect on Soil Carbon and Economic Returns* (King, 2002). In this report, King details the returns from forage crops at three locations. These include a brome/alfalfa crop at Burr, an alfalfa crop at Valparaiso, and an alfalfa crop at Star City, Saskatchewan for the 1998, 1999, and 2000 crop years. The results are presented in **Table 14**.

Table 14. Forage Crop Manure Trials 1998, 1999, and 2000.

	Treatment gpa	1998 Revenue/ acre	1999 Revenue/ acre	2000 Revenue/ acre	Average Revenue/ acre	Average Injection Expense/ acre	Average Net Revenue/ acre
Brome/alfalfa forage crop at Burr	Check	$17	$52	$19	$29	$0	$29
	3,300	$24	$110	$39	$57	$7	$50
	6,599	$29	$91	$46	$55	$14	$41
	13,198	$25	$103	$25	$51	$28	$23
Alfalfa forage crop at Valparaiso	Check	$40	$34	$22	$32	$0	$32
	3,300	$30	$35	$16	$27	$7	$20
	6,599	$47	$59	$16	$41	$14	$27
	13,198	$51	$59	$23	$44	$28	$17
Alfalfa forage crop at Star City	Check	$40	$34	$9	$28	$0	$28
	3,300	$30	$35	$11	$25	$7	$18
	6,599	$47	$59	$15	$40	$14	$27
	13,198	$51	$59	$12	$41	$28	$13

Source: Adapted from King, 2002

As can be seen, the application of manure to forage production provides a net economic benefit at all three sites. However, at both the Valparaiso and Star City sites, the lower application of manure resulted in lower net revenues than the "check" treatments.

A full cost analysis of this experiment using crop production expenses published by Saskatchewan Agriculture and Food is shown in **Figure 4.**

In this study, returns to forage crops vary greatly; however, as it can be seen, an important factor in the relative profitability is the low cost of production. Much of this is due to the assumed low transportation costs relative to wheat in which 15% to 30% of costs for wheat production are for getting the product to port. This supposition was made since it is assumed that the bulky nature of forages dictate that they will be consumed close to where they are produced.

Table 14. Forage Crop Manure Trials 1998, 1999, and 2000.

	Treatment gpa	1998 Revenue/ acre	1999 Revenue/ acre	2000 Revenue/ acre	Average Revenue/ acre	Average Injection Expense/ acre	Average Net Revenue/ acre
Brome/alfalfa forage crop at Burr	Check	$17	$52	$19	$29	$0	$29
	3.300	$24	$110	$39	$57	$7	$50
	6.599	$29	$91	$46	$55	$14	$41
	13.198	$25	$103	$25	$51	$28	$23
Alfalfa forage crop at Valparaiso	Check	$40	$34	$22	$32	$0	$32
	3.300	$30	$35	$16	$27	$7	$20
	6.599	$47	$59	$16	$41	$14	$27
	13.198	$51	$59	$23	$44	$28	$17
Alfalfa forage crop at Star City	Check	$40	$34	$9	$28	$0	$28
	3.300	$30	$35	$11	$25	$7	$18
	6.599	$47	$59	$15	$40	$14	$27
	13.198	$51	$59	$12	$41	$28	$13

Source: Adapted from King, 2002

As can be seen, the application of manure to forage production provides a net economic benefit at all three sites. However, at both the Valparaiso and Star City sites, the lower application of manure resulted in lower net revenues than the "check" treatments.

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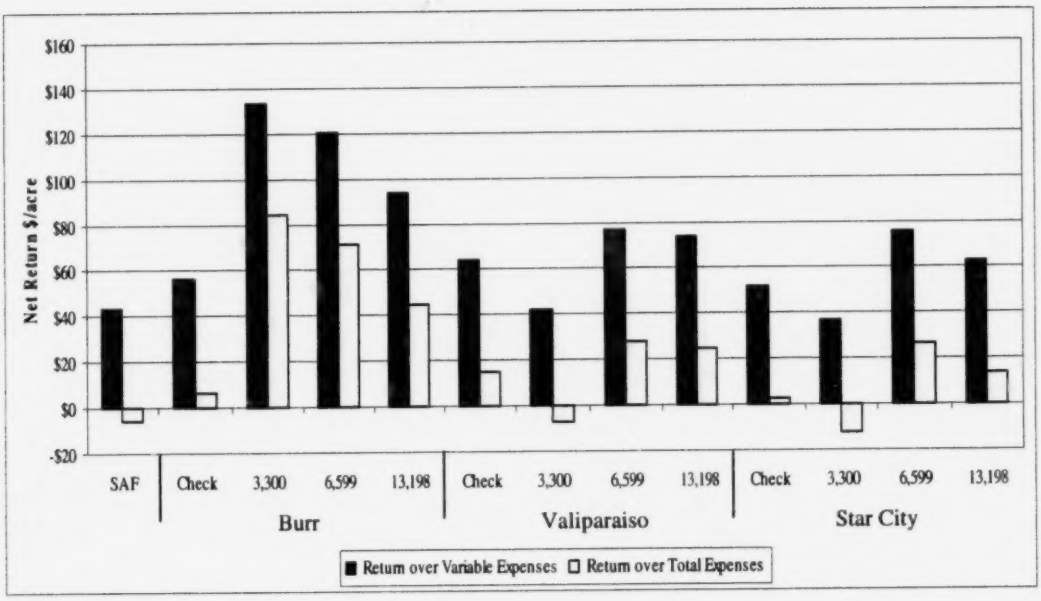

Source: Adapted from King, 2002 and
http://www.agr.gov.sk.ca/docs/crops/forage_pasture/forage_management_production/drylandforage03.asp

Figure 4. Returns to Forage Production.

As can be seen, the results vary depending upon site. The brome/alfalfa mix at the lower rate of manure application provided the highest net return at Burr, while at Valipraraiso and Star City, the 6,599 gpa rate was most profitable. For tabular analysis see **Appendix I**.

7. Results from PAMI Post-Emergent Swine Manure Application

This section outlines the economic performance of post-emergent swine manure application to wheat using data from two field experiments conducted in the Black soil zone over a four-year period near Humboldt, Saskatchewan. All materials and methods related to these studies were sourced and/or adapted from the Research Report, Progress Report, Post-Emergent Injection of Manure on Wheat or Barley (PAMI, 2003). The Section begins with a brief review of the effects of post-emergent swine manure application on wheat protein content and its value. Next, the yield responses are shown and briefly reviewed. Finally, the economic returns from the manure application treatments are presented and discussed.

7.1 Effect of Post-Emergent Swine Manure Application on Wheat Protein Levels

Wheat plots that received swine manure as a post-emergent application produced significantly higher grain protein compared to the undisturbed check (**Figure 5**). Protein levels generally increased linearly with the rate of manure application. Levels averaged about 0.8, 1.2, and 1.5 percentage points higher (than the undisturbed check) at manure application rates of 1,000, 2,000, and 3,000 gpa, respectively. However, since the resulting protein levels were often above the 15.5% limit, on which price premiums are currently paid, producers will be required to blend the wheat with lower protein materials to capture the full economic benefit from post-emergent swine manure application.

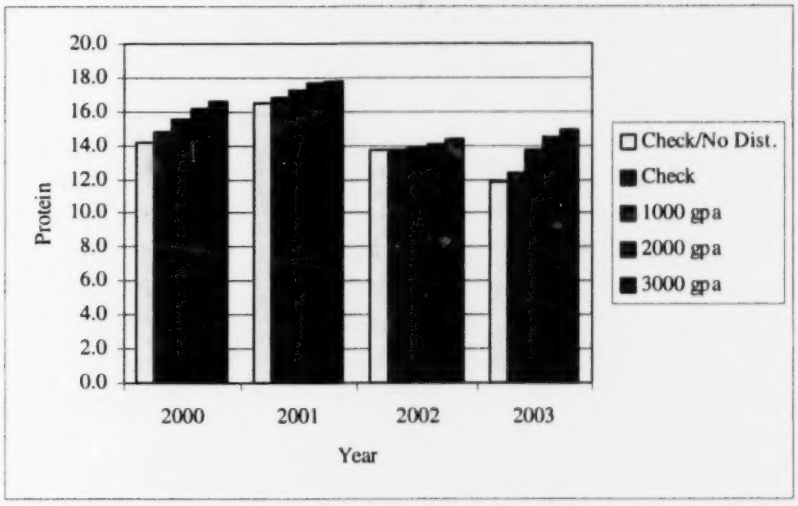

Figure 5. Effect of Post-Emergent Manure Application on Wheat Protein.

The enhanced protein contents from manure application were highly significant in 2000, 2001, and 2003 (**Figure 5**). However, in the drought year of 2002, there was no effect of manure application on wheat protein content. There was also little consistent effect of time of manure application on wheat protein content (**Figure 6**).

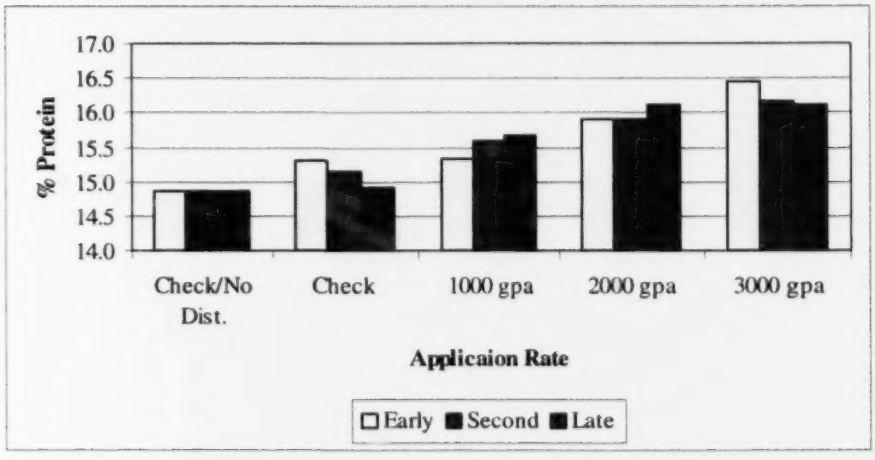

Figure 6. Annual Protein Content.

7.2 Yield Result

Yields varied greatly among years, mainly reflecting differences in spring soil water reserves and growing season rainfall (**Figure 7**).

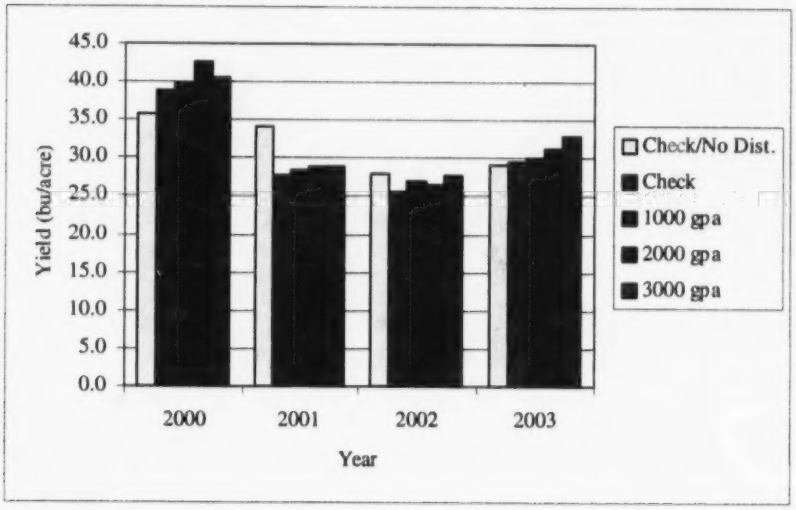

Figure 7. Yield Data for the Four Trial Years.

The highest yields were in obtained in the 2000 study year, with significant yield benefits resulting from manure application (average of 4 to 7 bu/ac) (**Figure 7**). In 2003, the yield benefits from manure application, although significant, were noticeably less (i.e., 2 to 4 bu/ac). While in 2001 and 2002 (i.e., the driest years, **Tables 15** and **16**) there was no yield response to manure application, with the highest yields obtained on the undisturbed check plots.

In terms of timing of application (early, second, or late), the late applications for the year 2000 had the highest average yield (45 bu/ac). However, as detailed in **Tables 15** and **16,** that year had abnormally high rainfall especially in the summer months. Conversely, late applications had the lowest yield in 2002 (<25 bu/ac); this can also be partially explained by abnormal rainfall for that year.

In the year 2001, yields were clearly the highest for early application (34 bu/ac), lowest for late application (26 bu/ac), while for 2003, yields were close to 31 bu/acre for early, second, and late application.

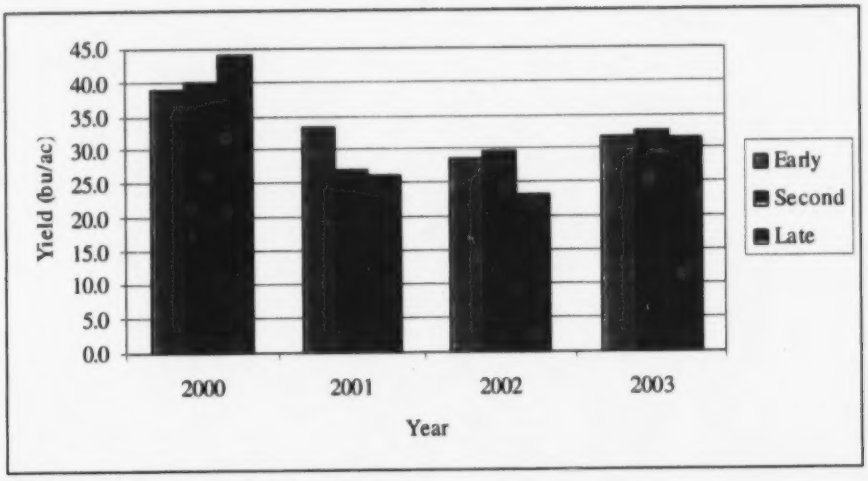

Figure 8. Yield and Application Timing.

The great variance in results (as presented in **Figure 8**)[6], suggest that the sample size is too small to make definitive conclusions on the role of application timing and yield response.

Tables 15 and **16** illustrate precipitation for the trial years.

[6] The values presented in **Figure 8** are averages of the 1,000, 2,000, and 3000 gpa manure applications.

Table 15. Precipitation over Trial Years.

	2000		2001		2002		2003		Normal
	Precip. (mm)	% of Normal	Precip. (mm)	% of Normal	Precip. (mm)	% of Normal	Precip. (mm)	% of Normal	Precip. (mm)
Jan	23.3	156	7.4	50	8	54	7.0	47	14.9
Feb	3.9	49	7.8	99	6	76	16.1	204	7.9
Mar	10.1	73	4.8	35	12.1	88	16.8	122	13.8
Apr	0.5	2	3.4	15	2.2	10	79.9	346	23.1
May	53	122	30.6	71	3.1	7	48.6	112	43.4
Jun	123.5	191	48.5	75	57.9	89	59.3	92	64.8
Jul	124.6	157	72.1	91	36.6	46	62.9	79	79.3
Aug	40.2	79	5.7	11	106.2	208	40.0	78	51.0
Sep	28.4	76	11.8	32	31.5	84	n/a	n/a	37.3
Oct	0	0	9.4	40	24.9	105	n/a	n/a	23.7
Nov	11.6	87	11	83	6.3	47	n/a	n/a	13.3
Dec	16.3	108	10.8	72	31.3	207	n/a	n/a	15.1
Annual	**435.4**	**112**	**218.5**	**56**	**314.0**	**81%**	**n/a**	**n/a**	**387.5**

Source: Adapted from Environment Canada Website
http://www.mscmc.ec.gc.ca/climate/climate_normals/index_e.cfm
Ryback,Don Don.Ryback@EC.GC.CA

Table 16. May, June, and July Precipitation.

Month	2000		2001		2002		2003		Average
	Precip. (mm)	% of Average	Precip. (mm)	% of Average	Precip. (mm)	% of Average	Precip. (mm)	% of Average	Precip. (mm)
May, June July	301.1	161	151.2	81	97.6	52	170.8	91	187.5

Source: Adapted from Environment Canada Website
http://www.mscmc.ec.gc.ca/climate/climate_normals/index_e.cfm
Ryback,Don Don.Ryback@EC.GC.CA

7.3 Average Net Revenue from Post-Emergent Manure Application

The economic benefits of post-emergent manure application are expressed as the difference between the net revenue per acre of the Check/No. Dist. treatment relative to each of the other four treatments: check (which received soil disturbance from the openers but no manure), 1,000 gpa, 2,000 gpa and 3,000 gpa. These net revenue values have the direct cost of manure application deducted (**Table 17**), but they do not include any value or cost for the manure itself nor any other production costs that are common to all treatments (e.g., seed, planting, harvesting, weed control). As such, the values represent the increase in net earning from the manure application treatments.

Table 15. Precipitation over Trial Years.

	2000		2001		2002		2003		Normal
	Precip. (mm)	% of Normal	Precip. (mm)	% of Normal	Precip. (mm)	% of Normal	Precip. (mm)	% of Normal	Precip. (mm)
Jan	23.3	156	7.4	50	8	54	7.0	47	14.9
Feb	3.9	49	7.8	99	6	76	16.1	204	7.9
Mar	10.1	73	4.8	35	12.1	88	16.8	122	13.8
Apr	0.5	2	3.4	15	2.2	10	79.9	346	23.1
May	53	122	30.6	71	3.1	7	48.6	112	43.4
Jun	123.5	191	48.5	75	57.9	89	59.3	92	64.8
Jul	124.6	157	72.1	91	36.6	46	62.9	79	79.3
Aug	40.2	79	5.7	11	106.2	208	40.0	78	51.0
Sep	28.4	76	11.8	32	31.5	84	n/a	n/a	37.3
Oct	0	0	9.4	40	24.9	105	n/a	n/a	23.7
Nov	11.6	87	11	83	6.3	47	n/a	n/a	13.3
Dec	16.3	108	10.8	72	31.3	207	n/a	n/a	15.1
Annual	**435.4**	**112**	**218.5**	**56**	**314.0**	**81%**	**n/a**	**n/a**	**387.5**

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Ryback,Don Don.Ryback@EC.GC.CA

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Month	2000		2001		2002		2003		Average
	Precip. (mm)	% of Average	Precip. (mm)	% of Average	Precip. (mm)	% of Average	Precip. (mm)	% of Average	Precip. (mm)
May, June July	301.1	161	151.2	81	97.6	52	170.8	91	187.5

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Table 17. Manure Spreading Costs per Acre.

Application Rate (gpa)	Cost per Acre (1-2 mile radius of lagoon)
Check/No Dist.	Nil
Check	Nil
1000	$9.70
2000	$19.40
3000	$29.10

The average net revenues without blending for the four-study years are shown in **Figure 9**. Overall, there was little economic benefit from post-emergent swine manure application, and in several instances, economic losses were incurred with some of the application treatments. These results suggest that the yield benefits obtained from applying swine manure were only sufficient to recover the direct costs of the manure application for six of the nine treatments (i.e., produced an average net revenue of about $5/ac) (**Figure 9**). These small but positive gains in net revenue represent the maximum breakeven values that producers would be willing to pay (above the direct costs of application) for the manure product itself. In the other three treatments, producers would need to be compensated for a portion of the direct manure application costs (presumably from the owner of the hog barn) in order to remain as well off as not applying or accepting any post-emergent swine manure (i.e., the undisturbed check).

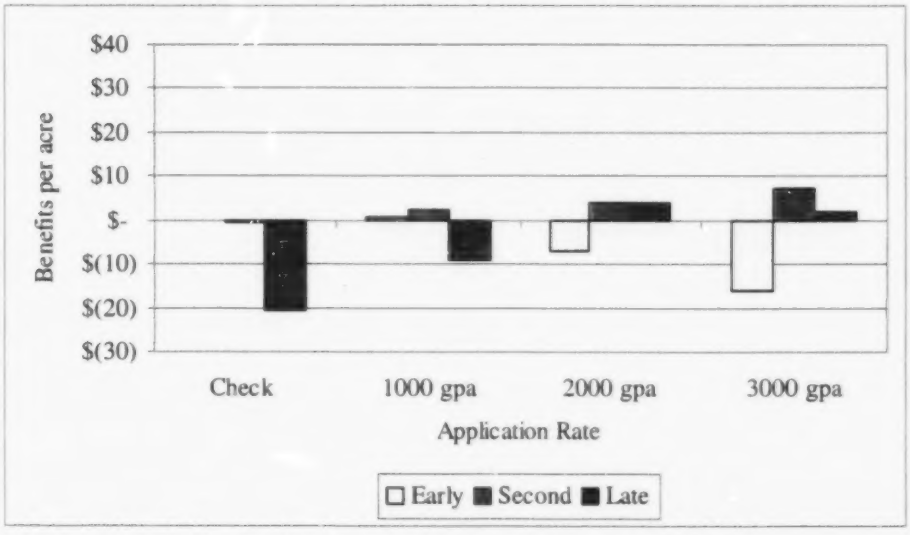

Figure 9. Average Benefits without Blending for 2000, 2001, 2002, and 2003.

When the economic benefits from manure application were calculated, including the value of protein enhancement derived from blending, the relative performance of the post-emergent manure treatments improved substantially, with most treatments displaying positive returns (**Figure 10**). Net revenues were highest for the early application timing (average of $11/ac), intermediate for the second period timing (average of $3/ac), and lowest (and a net loss) for late application ($-3/ac). Furthermore, net revenues were highest for the 1,000 gpa rate, and generally decreased as the manure application rate increased. In this case, producers would have manure applied in the early period could afford to pay a positive value for the manure product itself, ranging between $8 and $13/ac (depending upon rate of application). In contrast, producers applying the manure in the late application period would not generally earn sufficient revenue to recover the direct cost of the manure application (and thus, would not be willing to pay the hog barn for the manure itself).

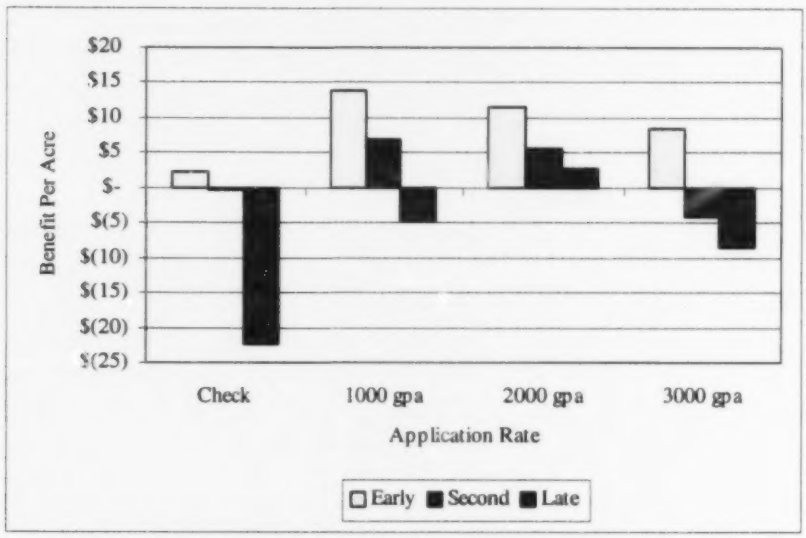

Figure 10. Average Benefits with Blending for 2000, 2001, 2002, and 2003.

7.4 Application Timing

Late application of manure to crops caused significant crop damage by the machinery used to apply manure. Timing of application corresponds roughly with the stage of crop development. This is presented in **Table 18**.

Table 18. Crop Leaf Stages.

	2000			2001			2002			2003		
	06-Jun	15-Jun	23-Jun	31-May	13-Jun	27-Jun	07-Jun	21-Jun	04-Jul	29-May	12-Jun	24-Jun
Site 1	3.3	4.6	6.8	2.2	5	8	2.5	5.5	late flag leaf	2.5	4.5	flag leaf, early heading
Site 2	3	3.7	6	2.8	5	7.5	2.5	5	late flag leaf	N/A	N/A	N/A

Source: PAMI, 2003

Economic benefits resulting from the first application of 1,000, 2,000 and 3,000 gpa, (2 to 3 leaf stage) when the plants have the best opportunity to recover from machinery damage, are $14 (1,000gpa), $12 (2,000gpa), and $8 (3,000gpa) per acre relative to the Check/No. Dist. case averaged over the two trials and over the three crop years. As can be seen, there are advantages to the early application of swine manure. In the four trial years, early application took place on June 6 (2000), May 31 (2001), June 7 (2002), and May 29 (2003). These applications took place when the crop was at the 3.3 and 3.0 leaf stages in 2000, the 2.2 and 2.8 leaf stages in 2001, the 2.5 and 2.5 leaf stages in 2002, and 2.5 leaf stage in 2003.

As can also be seen from **Figure 10**, the benefits to the second application of swine manure are lower than those for the early application. The benefits and losses of the second application tended to be negative and are only marginally beneficial for the 3,000 gpa application. In the four trial years, the second application took place on June 15 (2000), June 13 (2001), June 21 (2002), and June 12 (2003). These applications took place when the crop was at the 4.6 and 3.7 leaf stages in 2000, the 5.0 and 5.0 leaf stages in 2001, the 8.0 and 7.5 leaf stages in 2002, and 4.5 leaf stage in 2003.

In the three trial years, late application took place on June 23 (2000), June 30 (2001), July 4 (2002), and June 24 (2003). These applications took place when the crop was at the 2.5 and 2.5 leaf stages in 2000, the 5.5 and 5.0 leaf stages in 2001, the flag leaf/early heading stages for both sites in 2002, and flag leaf stage in 2003. The average results of the third application of liquid manure are also presented in **Figure 10**. In two of the three application rates, the result was reduced financial returns per acre (-$9 and 5$ per acre). However, the rate of 2,000 gpa had benefits of $6 per acre.

These results suggest that late application offers less benefit to farmers than earlier application, and it may cause more harm than good. This would be consistent with initial

assumptions that there would be diminishing returns at higher rates of application (3,000 gpa vs. 2,000 and 1,000 gpa), and that damage to the crop from application would result in lower returns from later application.

Nevertheless, these conclusions are rendered from averages and do not fully explore the detailed factors of each year. The effects on revenue of the three applications, early, second, and late, for each of the trial years are compared in **Figures 11** and **12**.

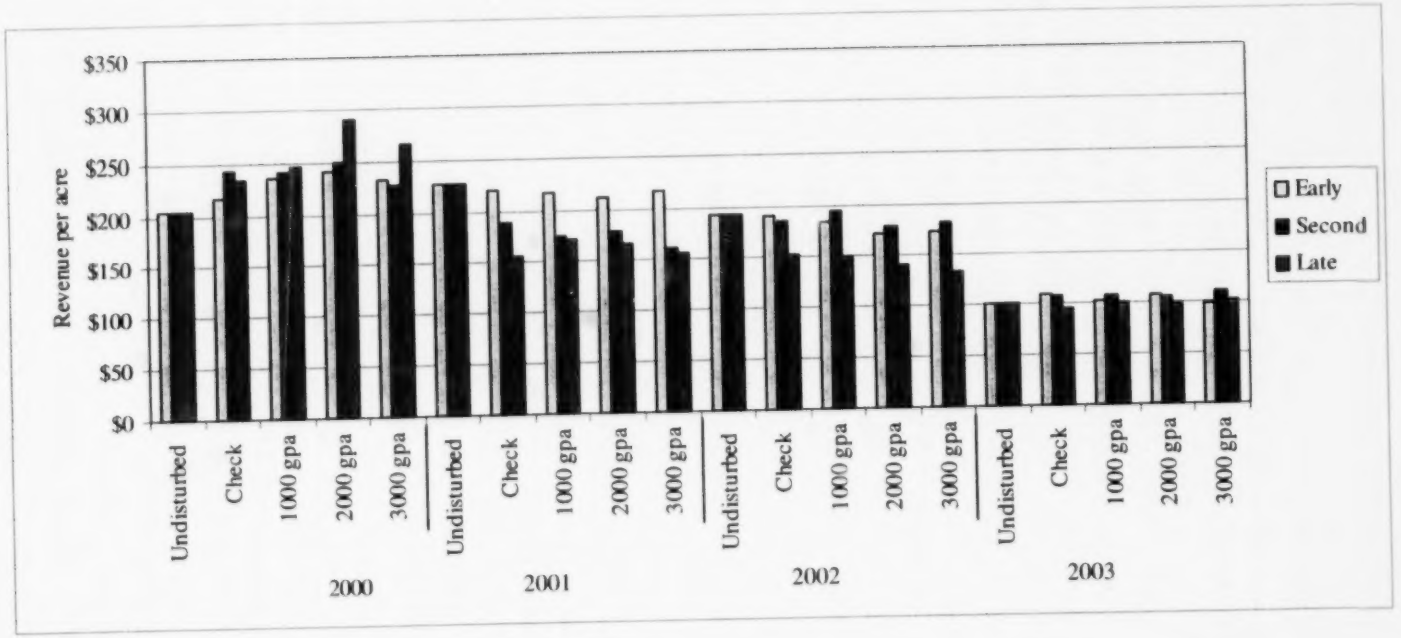

Figure 11. Net Returns per Acre over Trial Years.

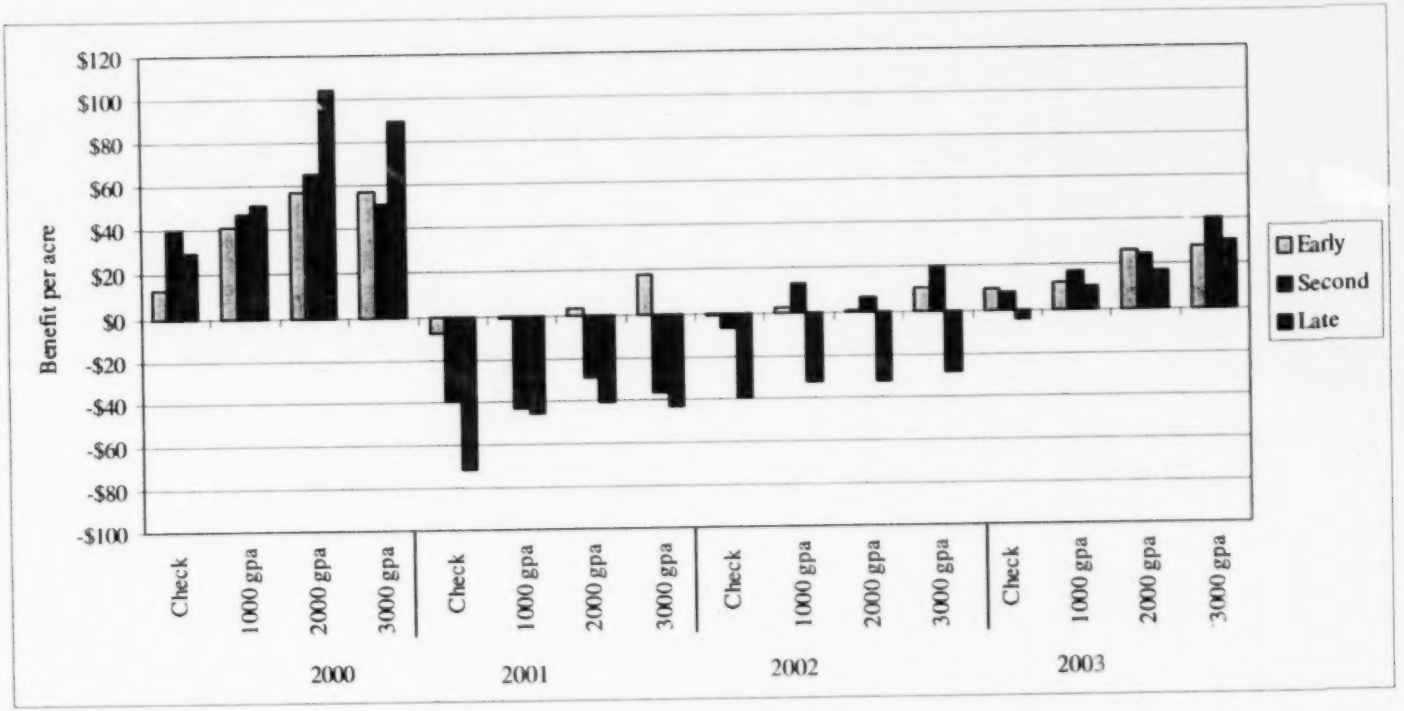

Figure 12. Net Benefits per Acre over Trial Years.

As can be seen from **Figures 11** and **12**, revenue and benefit per acre varies greatly depending on the trial year. Since climate is the factor, which varied the most between trial years, it can be suggested that these variances were determined by weather. For instance, the revenue and benefit are most positive for the late 3,000 gpa application in 2000. However, in the subsequent crop year, 2001, the late 3,000 gpa application was the most negative. By examining the precipitation data, 2000 had 112% of average precipitation, and for the months of June and July (when third application would have taken place), rainfall was 191% and 157%, respectively. In 200, there was only 56% of normal precipitation and 75% and 91%, respectively, for June and July. The conclusion of this analysis is that it may be too soon to "write off" the late applications of swine manure as doing such excessive damage to the crop that it would be considered not a worthwhile endeavor. Rather, the responsiveness of the crop and its ability to recover from machinery damaged due to late application are dependent upon moisture levels close to the time of application and requires subsequent trial years of study.

For more details of returns after expenses see **Appendix II**.

8. Comparison Between Manure Application Examples

This section of the report compares revenue from post-emergent manure application to fall application, application to forage crops, as well as SAF values for conventional cropping.

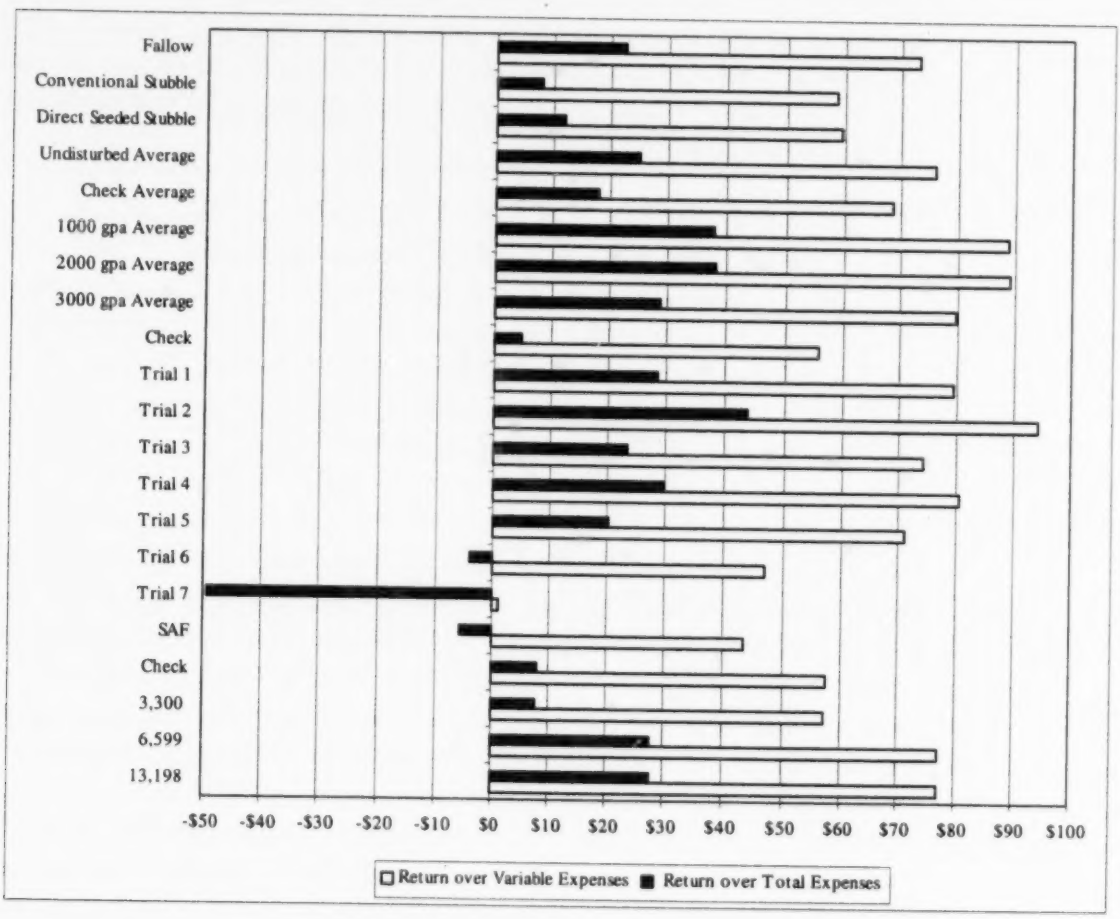

Figure 13. Comparison Between Returns for Manure Application.

Figure 13 shows the returns from fall manure application and application of manure to forage crops to the post-emergent studies conducted by PAMI. As can be seen, the 1,000 gpa and 2,000 gpa applications present revenues above all but one alternative (Trial 2 of application to forages). This suggests that post-emergent manure application potentially beneficial activity for farms within close proximity to hog barns.

9. Conclusion and Areas for Further Research

Given the results of the crop trials, it is possible to assert that post-emergent application of swine manure offers returns comparable to those for fall application or application to forages. However, it should be noted that the effectiveness of post-emergent manure application is highly dependent upon the amount and timing of precipitation. Application of manure shortly before rainfall in late June or early July would likely be ideal. Nevertheless, such a recommendation is unrealistic due to uncertainty over the weather. Unlike risk, which is quantifiable, uncertainty cannot be assigned a numeric value and plugged into a production equation.

> Outside economics, the terms risk and uncertainty are often used interchangeably; however, within economics these terms hold distinct and exact meanings. Risk is a distribution between known parameters and the probability of a specific outcome can be assigned a numerical value within a known distribution. Uncertainty also entails a random component; however, it lacks distribution parameters. Thus, no numerical values can be assigned to the mean and variance of a decision under uncertainty (Knight, 1921).

Farmers may, given Environment Canada forecasts, wish to have manure applied at the earlier mentioned times. However, all farmers would likely want application at the same time (prediction of rain the next day), and there would not be sufficient resources for all of them to receive manure at that time. Also, there are no guarantees that rain would fall. Thus, it appears as if it would be an un-resolvable situation of a pure gamble based upon uncertainty. Nevertheless, given more years of data for analysis, it might be possible to get better numerical values for this phenomenon.

This study set out to analyze the economics of post-emergent manure application to cereal crops based upon agronomic information provided by PAMI. The results of this study demonstrate that post-emergent manure application is beneficial, so long as the applications take place within one month after seeding, or before the crop is past the three-leaf stage. If there is rainfall shortly after late (post three-leaf stage), then great benefits can be realized in terms of yield and protein content. However, due to the uncertainty inherent to depending on the timing of such rainfall, it is unwise to apply manure to crops at such a mature stage.

As has been shown from this research, the importance of blending to realize benefits from manure application to cereals cannot be overstated. Any further research conducted on manure application should take into account protein and realizing its

benefits either through blending or by production of animal feed products that do not require much transportation.

The benefit to farmers for post emergent swine manure application to cereal crops remains unquantifiable given inseparability of the affect of manure from conventional fertilizer applied to trial plots and the small sample size in the PAMI trials. The subsequent section, Recommendations for Further Research, outlines suggestions of what further work are required to attain definitive benefits and willingness to pay.

9.1 Recommendations for Further Research

This study examined the returns to post-emergent swine manure application relative to conventional cropping, manure applied to forage crops, as well as fall application of manure. Such research can be expanded to include the following areas:

- Given that the agronomic studies have only had four crop seasons (2000, 2001, 2002, and 2003). This is a relatively small sample size and the small numbers problem is present such that there is considerable variation in the data set. Such variation in the results suggests that the data sets should be expanded to give more results for analysis. Thus, the most logical suggestion for further research is to continue this study over more crop years so as to increase the sample size such that a better reflection of a "typical" weather is reflected in the study.
- Barley Crops: Due to the potential for cultivating high yielding/high protein varieties of feed barley in proximity to swine barns, particular if this barley could be fed to the animals in the barn and that transportation costs would be much lower than for crops destined for port.
- Energy Crops: Given the large amount of biomass that is often associated with manure application to field crops, the technology and economics of gasifying this material to heat hog barns as a means of mitigating natural gas heating costs could be researched.
- Greater agronomic work into application technology such as spacing and the use of a closure wheel to limit burying of crops by dirt thrown up by the coulter.
- Research into crop yields in subsequent years for cropping on the same land that has received post-emergent manure treatment. Thus, examination of the residual effects.
- Futures agronomic trials to be done on plots of land that do not have conventional fertilizer so as to make the results of manure application more easily separable and hence quantifiable.
- Agronomic trials should be carried out to determine if crop damage can be reduced by carrying out post-emergent application at higher soil moisture content or at lower ambient temperatures.

Appendix I

Detailed Breakdown of Forage Trials

	Value from SAF	Brome/alfalfa forage crop at Burr				Alfalfa forage crop at Valparaiso				Alfalfa forage crop at Star City			
Manure Application (gpa)	-	**Check**	**3,300**	**6,599**	**13,198**	**Check**	**3,300**	**6,599**	**13,198**	**Check**	**3,300**	**6,599**	**13,198**
Gross Return (based on prices averaged from 1998-2000)	**$91**	**$88**	**$172**	**$166**	**$154**	**$96**	**$81**	**$122**	**$133**	**$84**	**$75**	**$121**	**$122**
Variable costs													
Manure Application Cost	$0	$0	$7	$14	$28	$0	$7	$14	$28	$0	$7	$14	$28
First year – Establishment Costs ($84.93 amortized over seven years @ 7% interest)	$16	$16	$16	$16	$16	$16	$16	$16	$16	$16	$16	$16	$16
Nitrogen fertilizer (50 lb./acre)	$15	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
One time – 40-foot fertilizer spreader	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Two times – mower conditioner	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6
Two times – baler (large round bales)	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
Bale hauling	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
Twine	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Property taxes	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
Total variable costs	$47	$32	$38	$45	$59	$32	$38	$45	$59	$32	$38	$45	$59
Other costs													
Interest on land investment	$13	$13	$13	$13	$13	$13	$13	$13	$13	$13	$13	$13	$13
Depreciation and interest on equipment investment	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36
Total other costs	$49	$49	$49	$49	$49	$49	$49	$49	$49	$49	$49	$49	$49
Total Variable and Other Costs	$97	$81	$88	$95	$109	$81	$88	$95	$109	$81	$88	$95	$109
Return over Variable Expenses	**$44**	**$56**	**$133**	**$121**	**$94**	**$64**	**$42**	**$77**	**$74**	**$52**	**$37**	**$76**	**$63**
Return over Total Expenses	**-$6**	**$7**	**$84**	**$71**	**$45**	**$15**	**-$7**	**$28**	**$25**	**$3**	**-$12**	**$26**	**$14**

Appendix II

Spring Wheat Crop Production Costs ($/Acre) 1999-2003

	Tillage Fallow Seeded Crop	Conventional Stubble Crop	Direct Seeded Stubble Crop	Average Undisturbed	Average Check	Average 1000 gpa Application	Average 2000 gpa Application	Average 3000 gpa Application
GALLONS OF MANURE	nil	nil	nil	nil	nil	1,000	2,000	3,000
REVENUE PER ACRE								
Protein Content	14.9	14.9	14.9	14.9	15.1	15.5	16.0	16.2
Estimated Yield (bu/ac)	33.5	29.0	29.0	32.6	30.7	31.7	32.7	32.3
Est. On Farm Market Price/bushel	$5.82	$5.82	$5.82	$5.82	$5.88	$5.99	$6.14	$6.21
Estimated Gross Revenue $/acre	$195.04	$168.84	$168.84	$189.73	$180.52	$189.88	$200.78	$200.58
Variable Expenses/acre								
Estimated Freight, Vancouver @$0.97/bu	$32.50	$28.13	$28.13	$31.62	$29.78	$30.75	$31.72	$31.33
Seed	$10.88	$10.88	$10.88	$10.88	$10.88	$10.88	$10.88	$10.88
Fertilizer - Nitrogen	$7.50	$15.00	$15.00	$15.00	$15.00	$0.00	$0.00	$0.00
- Phosphorus	$6.50	$6.50	$6.50	$6.50	$6.50	$0.00	$0.00	$0.00
- Manure application cost	$0.00	$0.00	$0.00	$0.00	$0.00	$9.70	$19.40	$29.10
Chemical - Herbicides	$16.60	$14.15	$17.49	$14.15	$14.15	$14.15	$14.15	$14.15
- Insecticides/Fungicides	$1.03	$1.03	$1.03	$1.03	$1.03	$1.03	$1.03	$1.03
- Others	$2.63	$2.63	$2.63	$2.63	$2.63	$2.63	$2.63	$2.63
Machinery Operating -Fuel	$12.69	$9.40	$6.58	$9.40	$9.40	$9.40	$9.40	$9.40
- Repair	$11.70	$8.30	$7.15	$8.30	$8.30	$8.30	$8.30	$8.30
Custom Work & Hired Labor	$5.25	$5.25	$5.25	$5.25	$5.25	$5.25	$5.25	$5.25
Crop Insurance Premium	$2.98	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Utilities & Miscellaneous	$8.50	$4.25	$4.25	$4.25	$4.25	$4.25	$4.25	$4.25
Interest on Variable Expenses	$3.01	$2.08	$2.06	$2.08	$2.08	$2.08	$2.08	$2.08
Total Variable Expenses	**$121.75**	**$110.16**	**$109.52**	**$113.66**	**$111.81**	**$100.98**	**$111.65**	**$120.97**
Other Expenses/acre								
Building Repair	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
Property Taxes	$4.81	$4.81	$4.81	$4.81	$4.81	$4.81	$4.81	$4.81
Insurance & Licenses	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81
Machinery Depreciation	$16.60	$16.60	$14.30	$16.60	$16.60	$16.60	$16.60	$16.60
Building Depreciation	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
Machinery Investment	$8.63	$8.63	$7.44	$8.63	$8.63	$8.63	$8.63	$8.63
Building Investment	$1.25	$1.25	$1.25	$1.25	$1.25	$1.25	$1.25	$1.25
Land Investment	$15.30	$15.30	$15.30	$15.30	$15.30	$15.30	$15.30	$15.30
Total Other Expenses	$50.80	$50.80	$47.30	$50.80	$50.80	$50.80	$50.80	$50.80
Total Expenses	**$172.55**	**$160.96**	**$156.82**	**$164.46**	**$162.61**	**$151.78**	**$162.45**	**$171.77**
RETURNS PER ACRE								
Return over Variable Expenses	**$73.28**	**$58.67**	**$59.32**	**$76.08**	**$68.70**	**$88.90**	**$89.12**	**$79.62**
Return over Total Expenses	**$22.48**	**$7.87**	**$12.01**	**$25.28**	**$17.90**	**$38.10**	**$38.32**	**$28.82**

Source: Adapted from Saskatchewan Agriculture, Food and Rural Revitalization. *"Crop Planning Guide 2003, "*. http://www.agr.gov.sk.ca/

Appendix III

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